TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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INCREASE IN MAXIMUM PRESSURES PRODUCED BY PREIGNITION IN INTERNAL COMBUSTION ENGINES.

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With the high compression ratio of the aviation engine, preignition is of frequent occurrence. That extremely high temperatures are a result, is fairly well recognized, but little attention seems to have been given to the pressures that prevail in the cylinder under these conditions. It need scarcely be pointed out, however, that accurate knowledge of the maximum pressure in the cycle is essential to the design of an engine that shall have a known factor of safety.

In the course of the investigation of the effect of compression ratio on altitude performance, which is being conducted for the National Advisory Committee for Aeronautics at the Bureau of Standards, the curves shown on Sheet No. 1 were obtained. The dotted line shows the pressure obtained with the engine operating normally, the solid line those obtained during preignition. A change of spark plugs was the only difference in engine conditions between the two runs. It appears that the charge is completely burned early in the compression stroke. It is then compressed and because of the loss of heat to the walls of the combustion chamber the first part of the expansion line falls below the corresponding compression line. As a result, the negative work of the first part of the expansion stroke is nearly equal to the positive work at the latter end, making the effective work of that cylinder practically zero.

Although the substance dealt with is not a perfect gas, the equations used in the following computation are sufficiently accurate to explain the pressure increase:

Let V_1, P_1 and T_1 be the volume, absolute pressure and absolute temperature at the beginning of the compression stroke, V_2, P_2 and T_2 corresponding values at the end of the compression stroke, and V_3, P_3 and T_3 corresponding values after the charge has been burned at constant volume. For the 8.3 compression ratio used, if we assume the value of "n" as 1.3 in the expressions

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^n \quad \text{and } T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{n-1}$$

Then $$P_2 = P_1 \ (8.3)^{1.3} = P_1 \ (15.7)$$

$$\text{and } T_2 = T_1 \ (8.3)^{0.3} = 1.89 \ T_1$$

If the absolute temperature at the beginning of the compression stroke is 350°C, the final temperature T_2 will thus be 662°C. Now assume the firing of the charge to result in a temperature increase in the mixture of 2000°C. (This value is chosen small to allow for any dissociation, heat loss to walls, etc., that may exist.)

$$\frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3} \qquad V_2 = V_3$$

$$P_3 = \frac{T_3}{T_2} P_2 = \left(\frac{2000 + 662}{662}\right) P_2 = 4 \ P_2 = 4(15.7)P_1 =$$

$$= \underline{\underline{62.8 \ P_1}}$$

In assuming the charge to be burned at the beginning of the compression stroke, let P_3, V_3 and T_3 represent the condition after the charge is burned at constant volume, but before it is compressed, P_2, V_2 and T_2, as before, representing the condition after the compression.

$$\frac{P_1V_1}{T_1} = \frac{P_3V_3}{T_3}$$

$$V_1 = V_3$$

$$P_3 = \frac{T_3}{T_1} P_1 = \frac{(2000 + 350)}{(350)} P_1 = 6.7 P_1$$

$$P_2 = P_3 (8.3)^{1.3} = P_3(15.7) = (6.7) P_1(15.7) = \underline{\underline{105. P_1}}$$

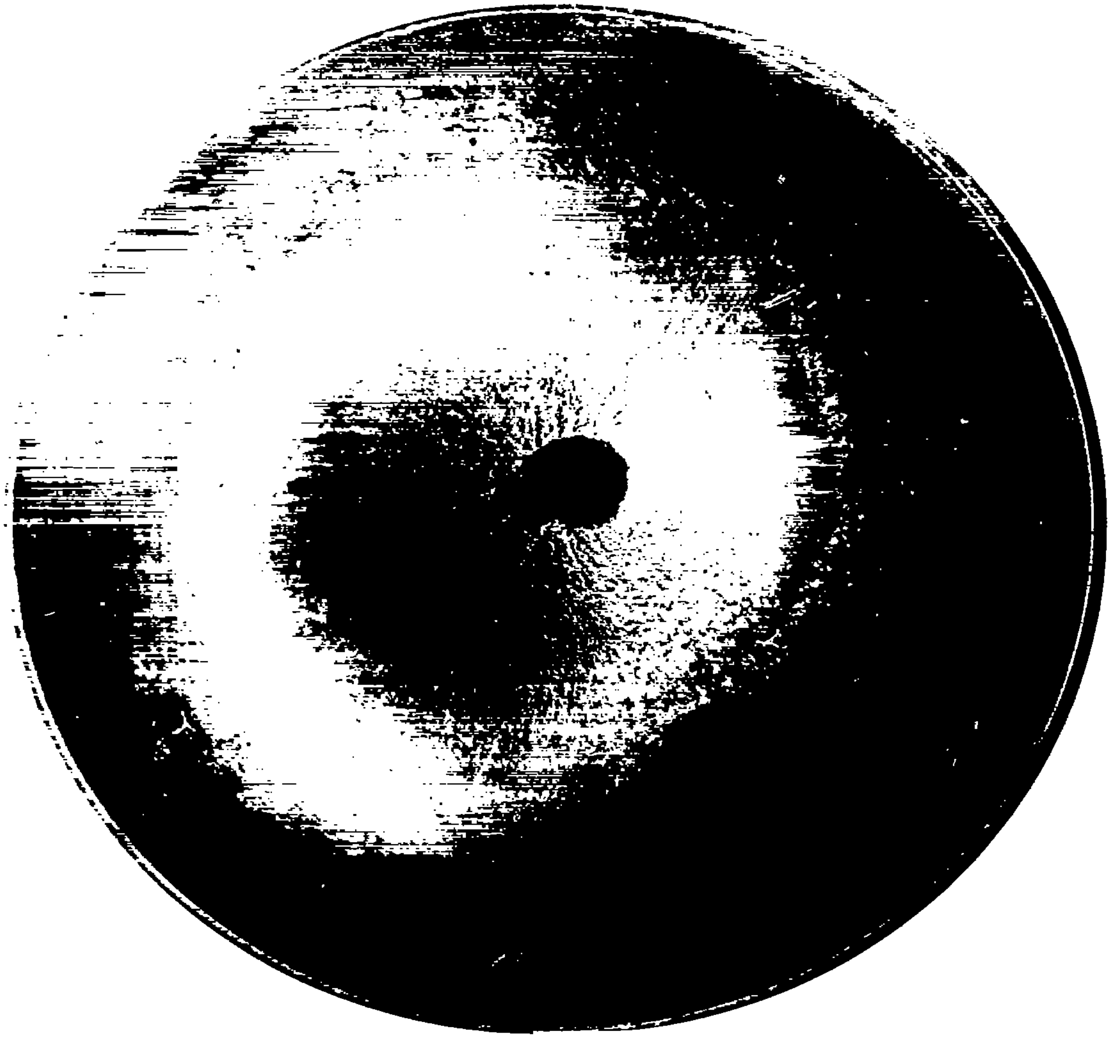
No attempt has been made to calculate accurately actual pressures or temperatures, but merely to show why the pressures obtained during preignition should be much greater than those during normal operation. The amount of this difference is, of course, influenced by the amount of dissociation, loss to combustion chamber walls, etc. Even Curve Sheet No. 1 does not adequately represent the magnitude of these pressures because with the high temperatures produced the amount of charge taken into the cylinder is somewhat decreased.

At 15,000 feet altitude where the maximum normal pressure ever obtained was 360 pounds per square inch, pressures of over 950 pounds per square inch were obtained during preignition.

The importance of making every effort to avoid preignition is apparent. Most important of all, however, is that the engineer realizes how much the pressures may be increased from this cause and governs the engine design accordingly.

The accompanying photograph will serve to add emphasis to this statement and explain why these experiments were temporarily interrupted.

July 7, 1920.
Bureau of Standards,
Washington, D. C.



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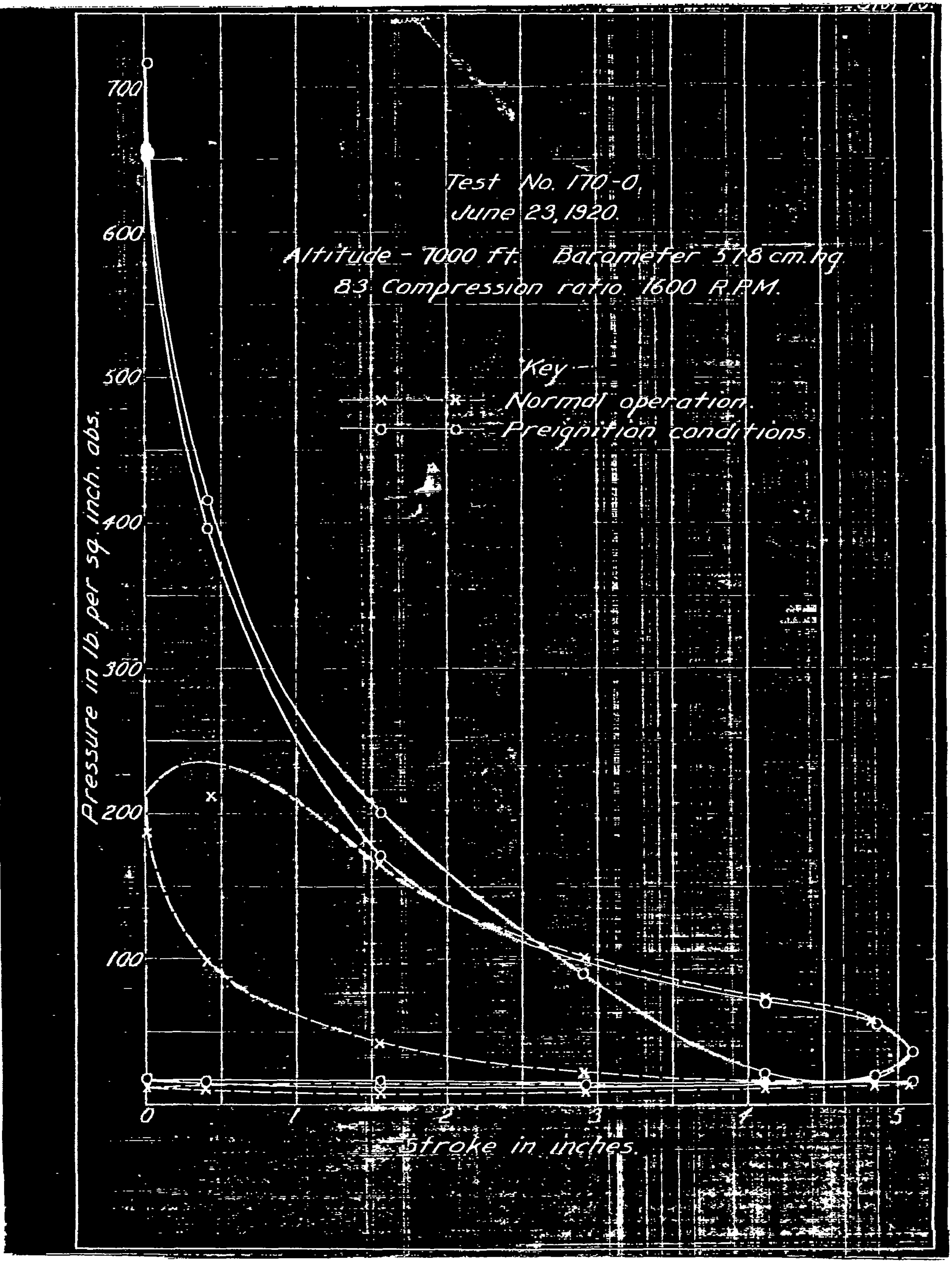
Test No. 170-0,
June 23, 1920.
Altitude - 7000 ft. Barometer 57.8 cm. hg.
83 Compression ratio 1600 R.P.M.
Key —
Normal operation.
Preignition conditions.
Pressure in lb. per sq. inch. abs.
700
600
500
400
300
200
100
0
1
2
3
4
5
Stroke in inches.